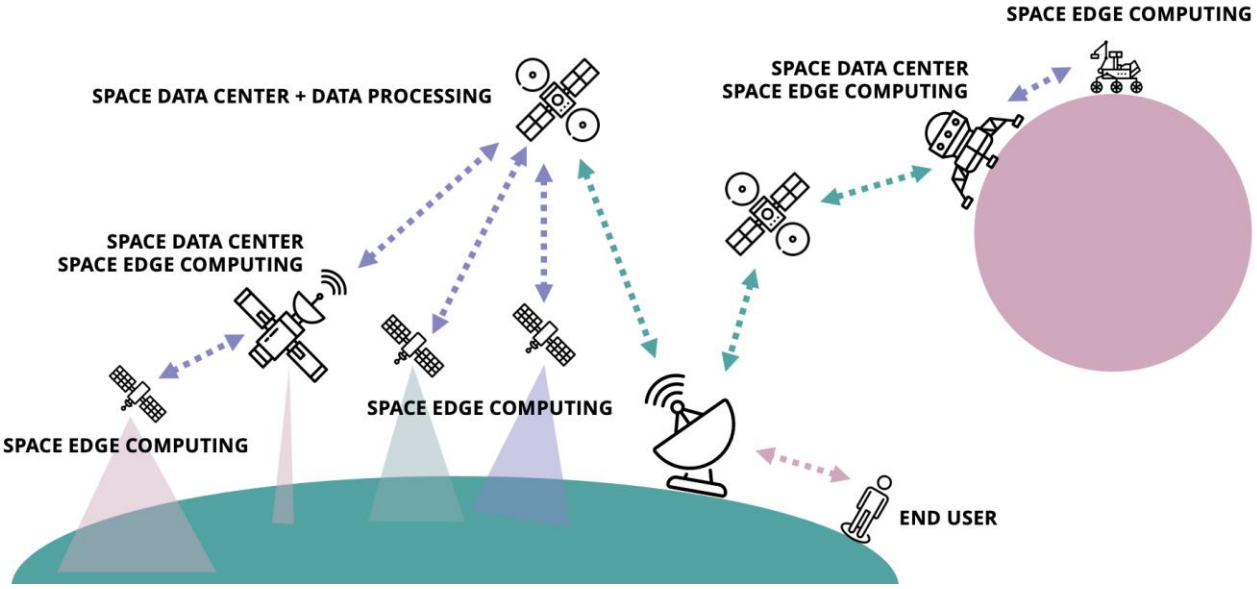
→ PREPARATION



SPACE-BASED DATA CENTRES – Study

Executive summary

OSIP: Wanted: your ideas for ESA's future space missions

Affiliation(s): IBM Research Europe (Prime), KP Labs (Subcontractor)

Activity summary:

The challenge in space data acquisition, e.g. for earth observation, lies in limited data-downlink capacity. Advances in onboard processing technology prompt exploration of deploying edge computing on satellites to alleviate data transport issues. This can be achieved through individual satellites or specialized networks akin to public cloud data centres. Use-case evaluation and stakeholder validation shaped system requirements for a generic Space Data Centre (SDC) architecture that was devised and simulated in Excel, integrating technology roadmaps and user needs. The analysis highlights a tipping point favoring onboard edge computing over raw data-downloading, essential for future space and satellite ecosystem's efficiency.

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Motivation & Background:

One of the bottlenecks of space-based data-acquisition (imaging and other earth-observation) is the availability of data-downlink capacity. With the prospect of increasingly powerful data-processing units from commercial applications (CPUs, GPUs, ASICs, FPGAs etc.), naturally the question arises, whether this technology may today and in the near future be deployed on-board satellites to preprocess data at the edge and thus mitigate such data-transport challenges and facilitate more cost-effective and low latency space-data based applications. Preprocessing data in space can either be done on individual satellites or following the successful scheme of (hybrid) public cloud datacenters, in the form of specialized satellites and networks thereof, exploiting a resource sharing scheme with very high utilization and thus the prospect of higher cost-effectiveness and flexibility.

Study Objectives & Goals:

1. Study feasibility for new mission concepts exploiting edge-computing in space.
2. Demonstrate the case for approval and funding of new optional projects.
3. Implement interdisciplinary discovery project for paradigm shifts and game changers.
4. Perform early “blue sky” research on potential breakthrough ideas which are 10+ years out.
5. Support the evolution of ESA by analyzing and testing new working methodologies.
6. Understand technical, operational, and economical challenges of deploying distributed, connected edge-compute infrastructure (space data centers) into orbit.
7. Identify key-technologies and their roadmap.
8. Quantify cost and performance of scenarios versus technology and system requirements.
9. Validate assumptions with key stakeholders and the community and disseminate findings.

Results and Conclusions:

The project started by collaboratively defining suitable use-cases for evaluating key-metrics of space-borne edge-compute infrastructure. Then, we derived user- and system requirements, validated by our advisory board from key industry and academic players. Based on high-performance, edge computing and public cloud data center insights, we subsequently derived a “generic” space data centre (SDC) system architecture, as a base for implementing a system simulation tool that was implemented in Microsoft Excel, exploiting spread-sheet capability with underlying visual basic macros.

The tool blends a large number of key technology roadmaps with user-requirements and use-case specific constraints. As results, it provides trends of figures of merits (cost per compute, weight per compute and cost per power) and comparative studies over time and between implementation- and technology options selected by the user. As a platform agnostic Excel spreadsheet, users can easily adjust the used source-data to either meet specific requirements or account for updated domain knowledge, allowing the tool to easily grow and improve over time.

Besides use-case specific insights, under current assumptions, the simulation results also clearly indicate an inflection-point where downloading raw-satellite data loses economic viability over edge-computing in space compressing data and extracting actionable insights. From this point in time on, massive computing and AI at the edge in space will no longer be an option, but rather be key for the entire space- and satellite ecosystem.

The results of the project are thoroughly documented in respective reports and the system simulator will be made publicly accessible to the community with use-case examples and a user-manual. Furthermore several workshops had been held and results were presented at the occasion of different international conferences and 2 journal papers are currently being drafted for submission.